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THE USE-POTENTIAL OF *QUERCUS ALIENA* VAR. *ACUTESERRATA* FOR URBAN PLANTATIONS – BASED ON HABITAT STUDIES IN THE QINLING MOUNTAINS, CHINA

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Abstract: Traditionally, a limited number of species and genera dominate the tree stock in streets and urban sites, and recent surveys in European and North American cities show that few species/genera continue to dominate. Yet, over the past decades, a growing proportion of those commonly used species have shown increasing difficulties to cope with urban sites. This has led to considerable and persistent arguments for using a more varied range of trees, including stress-tolerant species, at urban paved sites. This study examined forest systems occurring between 1300-2200 m asl. in the Qinling Mountains, China, in order to evaluate the oriental white oaks (*Quercus aliena* var. *acuteserrata* Maximowicz ex Wenzig) growth and development in warm and dry forest habitats and hence evaluate its potential for urban paved sites in northern parts of central Europe and in adjoining milder parts of northern Europe. In total, 102 oriental white oak where found in the studied plots and here showed very promising development in habitats experiencing drier conditions than those in park environments in Copenhagen, and is therefore interesting for urban paved sites were the demands of a greater catalogue of tolerant trees are highly needed.

Key words: Urban tree, Drought tolerance, Oriental white oak, Urban forestry

Introduction

Traditionally, a limited number of species and genera dominate the tree stock in streets and urban sites, and recent surveys in European and North American cities show that few species/genera continue to dominate [RAUPP & al. 2006; SJÖMAN & al. 2012a; COWETT & BASSUK, 2014]. Yet, over the past decades, a growing proportion of those commonly used species have shown increasing difficulties to cope with urban sites. Impermeable surfacing affecting both storm water run off and the urban heat island effect have resulted in tree decline and the increase of disease in the urban tree habitat. This negative trend, combined with the challenges of climate change and the threat of further future disease and infestations of vermin [e.g. TELLO & al. 2005; RAUPP & al. 2006; TUBBY & WEBBER, 2010] have led to considerable and persistent argumentation for the necessity of a more varied use and stress tolerant selection of tree species for urban sites [PAULEIT, 2003; SJÖMAN & al. 2012a].

A number of selection programmes with focus on trees for urban sites are in progress in several countries [SÆBØ & al. 2005]. However, the majority of these concentrate on the genetic aspect of species in current use, with the aim to select suitable varieties and genotypes [SANTAMOUR, 1990; MILLER & MILLER, 1991; SAEBØ & al. 2005]. In the case of northern Europe the majority of species used in cities originate from

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the native dendroflora, representing cool and moist site conditions were limitations of drought and pest tolerance continue to frame the main complications, albeit the intentions from these selection programmes [SAEBØ & al. 2005]. To supplement these selection programmes, additional tree species still awaits discovery and testing [DUHME & PAULEIT, 2000].

In order to achieve knowledge of a greater diversity of species adapted to urban sites, new innovating methods have to be developed. As water stress is widely argued to be the main constraint for tree growth and health in the urban environment [e.g. CRAUL, 1999; SIEGHARDT & al. 2005], research on drought tolerance of trees has classically focused on physiological reactions in the water balance/water use like transpiration rates, sap flow measurement and the hydraulic architecture of the tree [e.g. KOZLOWSKI & al. 1991; SPERRY & al. 1998; BREDA & al. 2006; DAVID & al. 2007; WEST & al. 2007]. These investigations give valuable information at the tree level but they are limited in their practical “every day use” for urban tree planners, arborists etc. [ROLOFF & al. 2009]. Instead, dendroecological studies can contribute to evaluate different tree species reaction and tolerance of e.g. drought. According to ROLOFF & al. (2009) this kind of dendroecological descriptions are seldom or not at all available for most species, which clearly points out the importance of this type of research in the selection process for “new” tree species for urban sites.

In natural habitats, trees have been stress-tested and selected over evolutionary periods of time. Some species have developed an extensive plasticity and tolerance of a range of environmental conditions while others have specialised in certain habitat types [RABINOWITZ, 1981; GUREVITCH & al. 2002]. For instance, steep mountain slopes with thin soil layers represent distinct habitat types, where the environmental parameters that define the particular habitat and separate it from other habitats have shaped the evolution of plants and acted as a filter that screens out many potential colonizing species not suited to the particular habitats. Investigating habitats experiencing similar conditions as urban environments in nature and studying the ecological background of these species would be of special interest for future selection of trees for use in urban fabric [FLINT, 1985; WARE, 1994; SÆBØ & al. 2005; ROLOFF & al. 2009]. Starting this process now is urgent, as tree selection is a long-term process.

From the perspective of the northern parts of Central Europe and in the adjacent, mild parts of Northern Europe (in the following abbreviated to the “CNE-region”) it is unlikely that the species poor native dendroflora can contribute to a larger variation of tree species with extended tolerance of the environmental stresses characterizing urban sites of the region [DUHME & PAULEIT, 2000]. In comparison, other regions with a comparable climate yet having a rich dendroflora may hold the potential to contribute new tree species and genera well adapted to the growing conditions in urban sites in the CNE-region [TAKHTAJAN, 1986; BRECKLE, 2002].

During the last decade extensive fieldwork have been carried out in the Qinling mountain range, China, in order to obtain an overall understanding of the species composition, structure and dynamics of the forest systems in the elevational zone where the climate is similar to the inner city environment across the CNE region [e.g. SJÖMAN & al. 2010]. This paper presents a study where the oriental white oak, *Quercus aliena* var. *acuteserrata* Maximowicz ex Wenzig, use-potential for urban sites in the CNE-region have been evaluated based on habitat studies in the Qinling Mountains. This study is initiated by the Swedish University of Agricultural Sciences to examine selection of site-adapted species for urban sites. The research hypothesis in this selection programme is that identification of "new" tree species for urban use can be gained through studies of natural habitats with similar site conditions as urban paved environment – where the field study in Qinling is one of the case studies on order to test this hypothesis. With the long-term aim to contribute to the selection of "new" tree species and genera well adapted to the growing conditions in urban sites in the CNE region the field work in China specifically focused on:

- identification of habitats in the Qinling Mountains where the oriental white oak are exposed to seasonally dry and harsh conditions;
- characterisation of the oriental white oaks performance in these habitats;
- presentation and discussion of the use-potential of the oriental white oak for urban sites in northern Europe.

In order to evaluate the use potential of the oriental white oak for the CNE-region origin from the Qinling Mountains, China, the field data is compared to urban environments of Copenhagen. In the comparison, the Copenhagen case is divided into paved respectively park environment in order to evaluate the broadness of the use potential.

Method and materials

Case study area

China is considered the most species rich region of the world [KÖRNER & SPEHN, 2002; TANG & al. 2006]. The Qinling Mountain range in the central, temperate part of the country forms a botanic border between the southern and northern regions of China, and consequently, it hosts a species rich flora [YING & BOUFFORD, 1998]. Shaanxi province, where the Qinling mountain range is situated, harbours 1224 wooded species [KANG, 2009], which can be compared to a total of only 166 wooded plants in the Scandinavian countries [MOSSBERG & STENBERG, 2003]. The relatively northern location of the mountain range combined with its altitudinal levels, makes it possible to find steep, south facing rocky and craggy slopes. Here, plants are exposed to cold winters and warm summer months with periods of intense drought [TAKHTAJAN, 1986; BRECKLE, 2002] much comparable to the climate expected in urban paved sites of the CNE-region.

The oriental white oak grows in the Qinling Mountains in the altitude 1300-2200m asl, belonging to the deciduous broadleaved oak forest zone [LIU & ZHANG, 2003]. The oriental white oak is the main canopy species throughout the zone. In the lower part (< 1200 m asl) the oriental white oak is co-dominating with *Quercus variabilis*, and in higher parts of the zone together with *Quercus wutaishanica.* These oak species dominate particularly on slopes, independently of direction, whereas the moist river valleys are characterised by mixed broadleaved forests with a large number of other canopy species [SJÖMAN & al. 2010].

Site description

The research was conducted in the northern part of the Qinling Mountain range within three different areas – Taibai Forest Reserve (34° 05'10" N 107° 44'46" E), Red

Valley Forest Reserve (34° 05’08” N 107° 44’52” E), and Siboshan (33° 42’08, 30” N 106° 47’16, 69” E).

Based on climate data for the Qinling Mountains, the altitude-zone from 1000-2000 m above sea level (asl.) was identified as the altitude where mean annual temperature and precipitation match the climate of urban sites in the CNE region. The mean annual temperature in the altitude 1000-1500 is 9-12 °C with a yearly precipitation on 650-1000 mm while the mean annual temperature in the altitude 1500-2000 is 8-9 °C with a yearly precipitation on 800-1000 mm (Tab. 1) [LIU & ZHANG, 2003; TANG & FANG, 2006]. The present situation of urban paved sites in Copenhagen represent a mean annual temperature of 8-12 °C when urban heat island effect is included (+1-3 °C) (DMI 2015; US EPA 2015) additionally with a yearly precipitation of 525mm (DMI 2015).

Tab. 1. Mean monthly temperature (°C) and precipitation (mm) at the study site.

Month	***Precipitation distribution (%)***	***Precipitation distribution at 1000-1500m asl (mm)***	***The mean monthly temperature at 1000-1500m asl (C)***	***Precipitation distribution at 1500-2000m asl (mm)***	***The mean monthly temperature at 1500-2000m asl (C)***
January	3 %	25	2	27	**0**
February	6 %	49,5	3	54	**1,9**
March	10 %	82,5	8	90	**3,9**
April	12 %	99	11,5	108	**7,9**
May	22 %	181,5	13	198	**8,9**
June	17 %	140,5	21,5	153	**14,5**
July	15 %	124	22,5	135	**15,5**
August	8 %	66	19,5	72	**13,9**
September	3 %	25	14,5	27	**11,9**
October	1 %	8	11	9	**7,9**
November	1 %	8	5,5	9	**2,9**
December	2 %	16,5	- 2	18	**- 4,1**
		Total 825,5 mm		**Total 900 mm**	

Location of plots

The field investigation was conducted during March-October with the assistance of botanical experts from the Northwest Agriculture and Forestry University, Yangling during the first two months. The task was to obtain an overall understanding of the species composition, structure and dynamics of the forest systems in relation to altitude and variation within the site conditions [SJÖMAN & al. 2010]. Special attention was given to identify exact locations of steep, south facing slopes with shallow soils and rock outcrop in order to establish the range of tree species that would grow in these locations. Subsequently, 20 study plots were strategically placed on recognized S facing slopes where extent of mature tree population on exceedingly rocky and/or steep gradients was the main criterion (Fig. 1). Homogeneous site conditions including oriental white oak trees determined the exact location and size of each plot. Plot sizes were of 10x10 m or 20x20 m and were located between 1150 and 1720 m asl. (Tab. 2). Due to human interference to vegetation and species composition plots below 1150 m asl, were not selected for the survey.

Fig. 1. The study plots were located at steep south facing slopes with shallow soils and rock outcrop

Measurement of plot data

For each plot, slope direction and steepness were measured and rock outcrop and cover of the herbaceous field layer were estimated. The exposure of bedrocks was based on FAO´ (2006). Field layer cover was estimated with intervals of 10%.

With the aim to parallel natural habitats and urban conditions in the CNE-region, soil texture, humus content and pH value was of special interest and focus. Soil samples were collected in three different depths (0-20, 20-30, 30-50 cm) from 10 pits randomly distributed in each plot [KLUTE, 1986; FAO, 2006]. For each depth, the samples were mixed before analyses [FAO, 2006]. Soil texture was analysed using the soil grain analyzer method **[**EHRLICH & WEINBERG, 1970] (Tab. 2), and organic matter was analysed with the $K_2Cr_2O_4$ method (Tab. 2), and pH using the potentiometric determination method (soil/water = 1:2.5) [TAN, 2005] (Tab. 2).

All trees were measured for diameter at breast height (DBH), total height and age in order to determine growth and development. To establish age, all trees were subjected to drilling as close to the ground as possible [GRISSINO-MAYER, 2003]. Tree positions were surveyed to distinguish canopy from understorey.

Tab. 2. Compilation of plot data. Rock outcrops in the plots were classified as N (None 0%), V (Very Few 0%–2%), F (Few 2%–5%), C (Common 5%–15%), M (Many 15%–40%), or A (Abundant 40%–80%).

Plot nr.	Altitude (m asl)	Slope direction	Slope steepness - degree	Number of soil sample to 30-50cm	pH	Rock outcrops	Fieldlayer cover (%)	Plot size (m)	Organic matter (g/kg)	Clay content (%)	Silt content (%)
1.	1720	South	53	10	6.5	V	40	10x10	9.6	1.7	40.6
2.	1620	South/Southeast	58	5	6.5	V	30	10x10	16.1	2.7	56.4
3.	1640	South	36	10	7.9	N	10	10x10	21.9	1.6	45.9
4.	1630	South	47	10	7.8	F	10	10x10	41.6	2.3	47.4
5.	1635	South	45	10	8.0	F	30	10x10	18.2	2.4	47.3
6.	1610	Southwest	45	10	7.5	F	10	10x10	27.1	2.1	44.4
7.	1650	South/Southwest	40	10	6.9	N	40	10x10	55.1	2.1	54.9
8.	1660	Southeast	45	9	6.1	C	30	10x10	12.1	1.7	44.3
9.	1620	Southeast	57	5	8.1	A	20	10x10	49.5	2.3	45.7
10.	1610	South	45	9	6.8	F	50	20x20	26.4	2.2	42.8
11.	1490	South	64	7	6.7	F	20	10x10	17.4	3.0	63.0
12.	1400	Southwest	43	10	6.4	F	10	10x10	18.8	2.0	48.2
13.	1590	South	40	10	7.2	V	20	10x10	41.3	2.7	59.4
14.	1560	South/Southeast	43	10	7.6	N	20	10x10	23.0	2.5	52.7
15.	1400	South/Southwest	38	5	7.0	C	30	10x10	44.5	1.8	44.3

16.	1350	South/Southwest	44	6	6.5	C	40	10x10	22.6	3.0	60.2
17.	1390	Southeast	43	7	5.8	F	30	10x10	16.8	3.0	58.6
18.	1360	South	45	5	6.5	A	10	10x10	44.8	1.9	47.5
19.	1260	South	45	2	6.4	C	30	10x10	51.1	1.6	45.7
20.	1370	South	44	6	6.9	V	40	10x10	31.0	2.5	53.8
Mean					**7.1**		**24.0**		**29.5**	**2.3**	**50.2**

Calculation of potential water stress

The potential water stress in the study plots was calculated and compared with data for the inner-city environment of Copenhagen, Denmark (Tab. 3). For the calculation of potential evapotranspiration, the regression by THORNTHWAITE (1948) was used, where monthly potential evapotranspiration was based on the values of temperature, number of sunshine hours per day and cloudiness. Sunshine hours per day were estimated on a monthly basis by combining information about day length [MEEUS, 1991] and days with rainfall as indicator for cloudiness [LIU & ZHANG, 2003]. Cloudiness is 10% of the total day length except the rainiest month (May, June and July) where cloudiness is 50% [LIU & ZHANG, 2003]. Since data of water runoff was not available for the study plots, a similar area of topography and vegetation characteristics in the region of Yangping was applied as a criterion [LIN & al. 2007]. The annual precipitation rate in Yangping exceeds Qinling with 215mm, yet data was considered suitable as the distribution and intensity of rain closely correlated with the studied terrain.

Estimates of water runoff data for park respectively paved environments in Copenhagen was based on P90 (2004), concluding a 10% runoff from park environment and an expected 70% water runoff for paved sites.

Tab. 3. The accumulated water netto difference (mm) in the study sites additionally with park respectively paved environments in Copenhagen

Qinling Mountains	jan	feb	mars	april	maj	juni	juli	aug	sep	okt	nov	dec
1000-1500m asl	2.5	11.4	12.3	-0.7	26.3	-1.5	-39.3	-114.4	-168.4	-206.8	-221.2	-215.0
1500-2000m asl	2.7	8.6	17.6	11.6	49.7	48.1	36.7	-16.0	-69.3	-106.5	-121.0	-114.2
Copenhagen												
Park environment	25.9	49.9	63.1	66.1	41.1	34.3	13.0	-40.6	-63.0	-79.1	-63.2	-42.1
Paved environment	6.7	12.1	6.7	-22.1	-84.9	-152.3	-223.4	-310.6	-361.8	-392.9	-398.0	-395.5

Calculation of growth data

In order to evaluate any difference between oak trees growing in lower terrain (<1500m asl.) in a warmer and drier climate compare with oak trees in higher altitudes (>1500m asl.) a growth pattern where calculated by a regression in Minitab (Minitab 16 Statistical Software).

Results

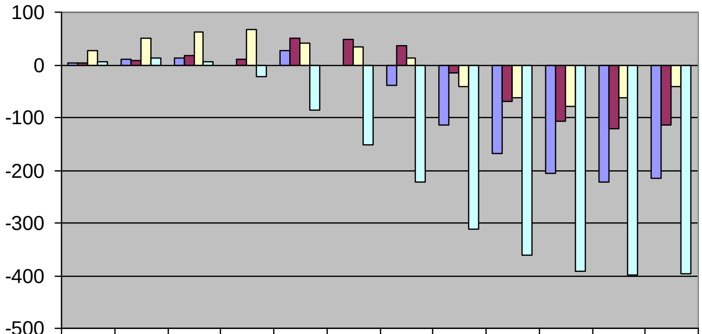
Site conditions

In all plots the soil depth was at least 50 cm, indicating tree root penetration into deeper grounds (Tab. 2). However, shallow bedrock and rock outcrops partly limit the soil depth for some of the plots (Tab. 2). The texture composition is comparable between all plots, with high to very high levels of silt (mean 50.2%) and low contents of clay (mean 2.3%) (Tab. 2). Also the organic matter content is low across the plots (mean 29.5 g/kg) (Tab. 2).

Cumulative water net difference

Due to higher precipitation and lower temperatures in higher altitudes (1500-2000 m asl) the water stress status is apparently smaller and occur later in the season compare to the sites in lower terrains (1000-1500 m asl) (Tab. 3). As Fig. 1 illustrates, current conditions in Qinling Mountains at 1000-1500 m asl, experience partial water stress in April and June and more severe water stress towards July and the remaining part of the growing season. In the altitude 1500-2000 m asl, a partial water stress occur first in August and thereafter in a less dramatically trend compare to the situation in lower terrains (Fig. 2).

In a compilation with Copenhagen, the study sites, regardless the altitude, experience warmer and drier site conditions compare to park environments in Copenhagen while they experience less water stress compare the situation in paved sites (Fig. 2).



	Jan	Feb	Mars	April	May	June	July	Aug	Sept	Oct	Nov	Dec
1000-1500m asl	2,5	11,4	12,3	-0,7	26,3	-1,5	-39,3	-114	-168	-207	-221	-215
1500-2000m asl	2,7	8,6	17,6	11,6	49,7	48,1	36,7	-16	-69,3	-107	-121	-114
Copenhagen (park environment)	25,9	49,9	63,1	66,1	41,1	34,3	13	-40,6	-63	-79,1	-63,2	-42,1
Copenhagen (paved environment)	6,7	12,1	6,7	-22,1	-84,9	-152	-223	-311	-362	-393	-398	-396

Fig. 2. The accumulated water netto difference (mm) in the two studied altitudes compare to park respectively paved sites in Copenhagen.

Species composition and performance

In total, 102 oriental white oak where found in the studied plots, 11 below 1500 m asl, and 91 above 1500 m asl.

Among the oak trees the majority have their vertical position in the canopy layer in the vegetation structure, regardless the altitude zone. Among the oak trees found in the plots below 1500 m asl., only one out of 11 where found in the understorey layer while 56 out of 91 oak trees in the plots above 1500 m asl where found in the canopy layer which indicating a high tolerance for warmer and thereby drier conditions existing in the canopy layer compared to underneath the tree crowns (Fig. 3).

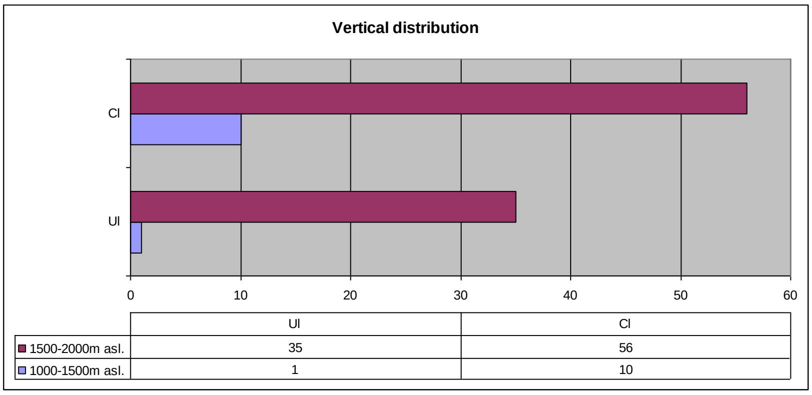


Fig. 3. The vertical distribution of the oriental white oak found in the studied plots separated between understoery layer (Ul) and canopy layer (Cl).

In a attempt to evaluate the growth pattern of the oriental white pine in the two studied altitude zones, growth tables have been completed, where height and diameter growth is match with the age (Fig. 4 and 5). Concerning height growth the oak trees in lower altitudes (<1500 m asl.) have a yearly mean growth rate of 0.28 m compared to 0.23 m tress in plots >1500 m asl. (Tab. 4). The calculations presented in Tab. 4 and 5 are based on rather few individuals (102 trees), especially in lower elevation (11 trees), but can still be used as an indicator of their growth rate in this climate and site conditions. Concerning the diameter growth the oak trees in lower altitudes have a slightly larger average growth compare to trees in higher terrains (Tab. 4). This above mentioned pattern is also illustrated in Fig. 4 and 5 where the trees in lower altitudes have a slighter stronger growth. However, concerning diameter growth illustrated in Fig. 5 show that the studied oak trees in higher altitudes show a stronger growth after 50 year.

Tab. 4. Yearly mean increment in height (m) and DBH (cm) of oriental white oak in the study sites divided between altitudes.

Plot area	Yearly Height Growth (m)	Yearly Diameter Growth (cm)	Number of trees	Size of an 15 year old tree	Size of an 50 year old tree
1000-1500 m asl	0.28	0.38	11	4.2/5.7	14/19
1500-2000 m asl	0.23	0.34	92	3.5/5.1	11.5/17

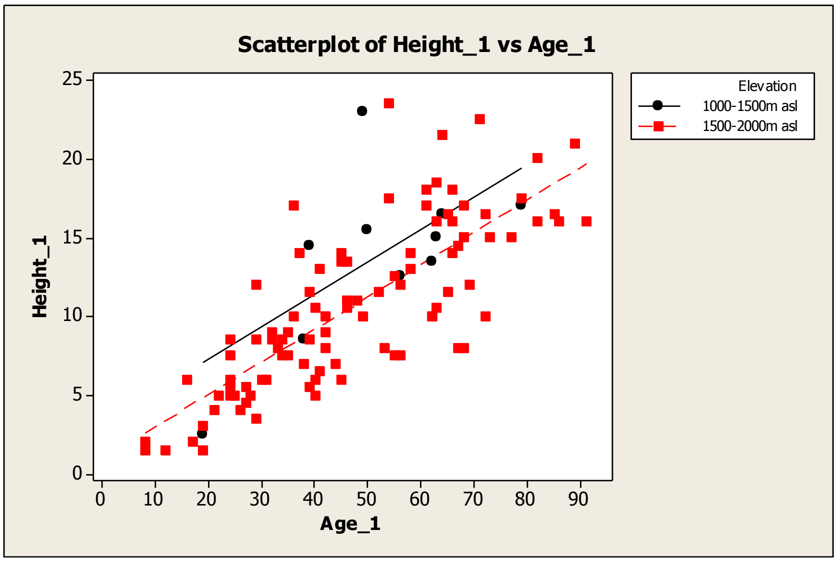


Fig. 4. Height increment (cm) of oriental white oak in two altitudes (1000-1500 m.a.s.l. and 1500-2000 m.a.s.l.) as a function of tree age (years).

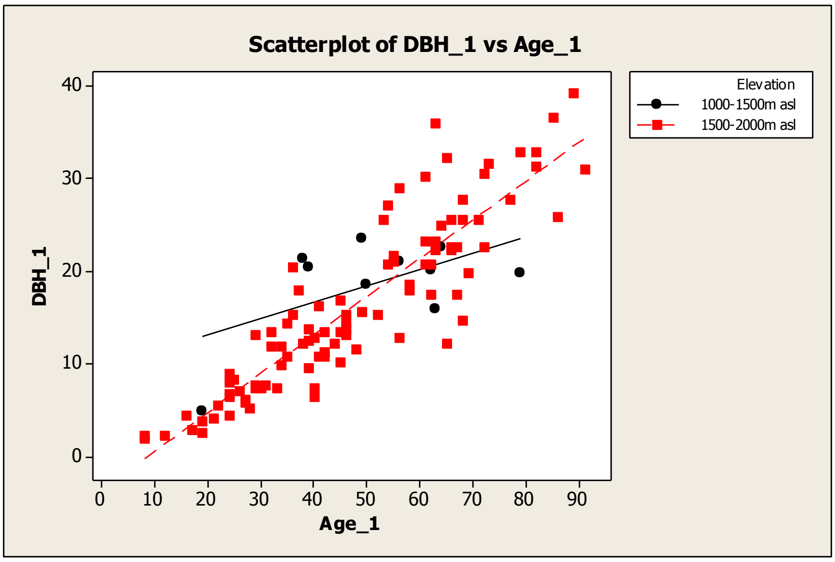


Fig. 5. DBH increment (cm) of oriental white oak in two altitudes (1000-1500 m.a.s.l. and 1500-2000 m.a.s.l.) as a function of tree age (years).

Discussion

As has been suggested by a number of authors, investigating the ecological background and performance of species growing in habitats that naturally experience drought during the growing season and winter temperatures similar to those of inner-city environments provides a sound and reliable selection method [FLINT, 1985; WARE, 1994; DUCATILLION & DUBOIS, 1997; BROADMEADOW & al. 2005; SÆBØ & al. 2005; ROLOFF & al. 2009; SJÖMAN & al. 2012b]. This study examined forest systems occurring between 1300-2200 m asl. in the Qinling Mountains, in order to evaluate the oriental white oaks (*Quercus aliena* var. *acuteserrata*) growth and development in warm and dry forest habitats and hence evaluate its potential for urban paved sites in the CNE-region. When comparing the study sites with urban paved environments in Copenhagen, Denmark, the trees in lower altitudes (<1500 m asl.) had a closer match with urban paved sites but had a later negative water netto difference and also a less extreme development during the season compare to paved environments in Copenhagen (Fig. 2). The trees in higher altitudes (>1500 m asl.) had an even less match with paved environments due to a cooler climate and hence a less dramatic evapotranspiration over the season. The conclusion from this is that in order to succeed growing oriental white oak in inner-city environments it is necessary to create larger planting pits or/and complement the plantations with storm water management which makes it possible to increase the soil water content compare to traditionally planting pits in paved environments [SIEGHARDT & al. 2005]. Furthermore, even the high levels of silt in the study plots indicate a rather good water holding capacity [BRADY & WEIL, 2002]. However, the high level of silt and the lack of vegetative field layer cover in many plots the surface can have a tendency to form a hard crust, which can cause extensive water runoff [BRADY & WEIL, 2002]. This water runoff in the plots can be of significant importance and to a rather large proportion due to rather steep slopes within the study sites which can in fact create much drier conditions in the studied sites that the data in his paper present [SJÖMAN & al. 2010]. Therefore it is possible to rank the oriental oak as a promising species for paved environment, especially the genotypes from lower altitudes since they have over evolution adapt to a warmer and dryer climate compare to trees in higher altitudes. Yet, further evaluation has to be done, including evaluation of the traits behind the genotypes tolerance towards drought and the capacity of these traits. For example, it is necessary to evaluate differences between avoiding respectively tolerating traits and how well these are and its combination such as turgor loss point and other leaf traits [e.g. SCHULZE & al. 2005; LAMBERTS & al. 2008]. Through this following evaluation more detailed information concerning their tolerance can be gained.

The majority of the oaks studied had their vertical position in the canopy layer in the vegetation structure, regardless the altitude zones studied, indicating that the species is rather shade intolerant, which is also presented in other literature [MENITSKY, 2005]. Noticeably, is that there were only one out of 11 trees that were found in the understory in the plots below 1500 m asl., while 35 out of 91 oak trees in higher altitudes (>1500 m asl.) were found in the understory. From a plant physiological perspective, shade and drought is a very hard combination of stresses for plants in order to capture resources for survival and/or competitions [GRIME, 2001], which might make the number of trees in the understory few in lower altitudes compare with the number of trees in cooler and moister habitats in higher altitudes. Nevertheless, it is important to keep in mind that the number of oak trees found in lower altitudes is rather few which makes above conclusion weak and need further studies. From an urban forest perspective this might however be a useful reflection since the built up structure in urban environments be able to create dry and shaded sites where the oriental white oak might is a less appropriate plant material. Furthermore, when the age distribution between analyse oak trees (Fig. 4 & 5) it is obviously that the main age distribution is between 20-70 years, indicating a very limited occurrence of young individuals in the plots. The lack of young trees indicates a pioneer strategy, with high demands for sunlight and has therefore difficulties in establishing under an existing tree canopy, which is a trait among many broadleaved oak species [JOHNSON & al. 2009].

This first stage in the selection process with dendroecological habitat studies can screen out species showing slow and/or underdeveloped growth in habitats similar to urban inner-city environments. This allows the focus to be directed towards the species in these natural sites that develop rapidly into large trees. This first stage consequently identifies genotypes of the species that ought to be included in the following steps at an early phase of the procedure [SJÖMAN & al. 2012b]. In the Qinling Mountains of China the oriental white oak shows very promising development in habitats experiencing drier conditions than those in park environments in Copenhagen, and is therefore interesting for urban paved sites were the demands of a greater catalogue of tolerant trees are highly needed.

This study focused on trees that in their natural sites are exposed to warm and dry growth conditions, since water stress is argued to be the main constraint for tree growth and health in urban environments [e.g., CRAUL, 1999; HOFF, 2001; SIEGHARDT & al. 2005; NIELSEN & al. 2007; ROLOFF & al. 2009]. It is important to bear in mind that this process with dendroecological habitat studies in order to identify potential urban trees is just the first step in the selection process. Further research is necessary in order to evaluate the species tolerance towards warm and periodically dry growth conditions in another geographical area and towards other stressors, such as de-icing substrates or air pollution. Nevertheless, this approach constitutes a faster and more effective route, since subsequent selection work can focus on species with high potential for the purpose instead of testing species randomly. Dendroecological studies, as presented in this paper, contribute to an ecological understanding that provides for a much wider knowledge base in the selection process, thus helping to evaluate the reaction, tolerance, and performance of different tree species to different stressors. Furthermore, dendroecological studies provide valuable guidance regarding the use potential of species, which can be of importance in their subsequent evaluation in full-scale plantations in urban environments.

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